

MATERIALS & ME

Created for **SPICE** by scientist Chris Woan and teacher Brett Cornelison

Fall 2008 / Spring 2009

LESSON 1: OVERVIEW ON MATERIALS

KEY QUESTION(S): What are the basic classifications of the types of materials in our daily lives? What do we already know about how materials are chosen for a particular application? (and) What environmental concerns should people have about using different types of materials?

SCIENCE SUBJECT: Technology and Environmental Sciences

GRADE LEVEL: 8th

SCIENCE CONCEPTS: Materials Classifications, Selection, and Environmental Health

OVERALL TIME ESTIMATE: 50 minutes

LEARNING STYLES: Visual, Auditory, and Kinesthetic

VOCABULARY:

- Metallic bonding
- Metals
- Corrode
- Ionic bonding
- Ceramics
- Compounds
- Covalent bonding
- Plastics
- Polymers

LESSON SUMMARY: Students are provided with the opportunity to synthesize their individual and collective understanding about materials selection and usage through a 'Gallery Walk' activity following a brief introductory lecture. The subsequent follow up to the Gallery Walk activity will help introduce and inspire concern on materials and their potential effects on the environment.

STUDENT LEARNING OBJECTIVES:

The student will be able to:

1. Identify the use of materials in their daily lives.

2. Consider positive and negative effects of a materials selection choice.
3. Identify characteristic properties of certain types of materials.
4. Provide insight into how conservation takes place in their family units.

MATERIALS:

1. "Overview of Materials Selection" Powerpoint Slide
2. Computer with internet access and projector
3. Six poster paper (12" x 17" ish)

BACKGROUND INFORMATION:

This first lesson needs to link what students originally were taught about chemistry and bonding to various materials they see in everyday life. The lesson should follow instruction about bonding and thus students can take their concept of bonds and make distinctions of how properties result from the type of bonding. An alternative use of this lesson is as a preface to the concepts of bonding since the student can take the macroscopic properties they see with these classes of materials and translate them to the bonding level relationships of a material's atoms.

Traditionally, materials science identifies the basic materials that we use in the following categories: Metals, Ceramics and Plastics. In general, each type of material consists of one or more types of bonding: Metallic, Ionic, and Covalent Bonds. Mechanical properties and electronic properties manifest themselves from these three types of bonds.

Metallic materials are made of metal atoms from the periodic table. The **metals** represent a large portion of the periodic table. With the exception of Hydrogen, all elements to the left of the zig-zag line are metals. Metals are very good

conductors of electricity and heat and does not allow light to pass through. When polished, they give off a lustrous appearance (and are thus used heavily in jewelry). They are usually used in applications which require something that is strong, yet deformable- and are most especially suited for high temperature applications such as in airplanes, cars, trains, and many tools. Metals consist of **metallic bonding**, which is usually represented as a positive metal nucleus sitting next to one another surrounded by a sea of electrons. What that means is that the electrons are not bound to a particular nucleus of a metal atom but are bounded to the entire unit. When a voltage source (such as a battery) is connected, the sea of electrons is free to move. For that reason metals are very well suited in applications requiring the conduction of electricity such as in wires, plugs, and other electrical terminals. One of the issues with metals is that they tend to react with oxygen in the air and thus **corrode**. A familiar form of corrosion is that of Iron (Fe) which corrodes to form Iron Oxide or more commonly known as rust. This corrosion results in many structural failures.

The next class of materials are ceramics. Ceramics actually comes from the greek word Keramos which means fire-earth and relates to the processing of rock and earth with fire to make a useful material. Ceramics are **compounds** between metallic and nonmetallic elements. They consists of a wide range of common materials including clays, cements, and glass. Many ceramics can be thought of as corroded metals. As such, their atoms are generally held together through **ionic bonding** where an electron or electrons are transferred from the metal to the nonmetallic species thus giving both atoms a stable octet configuration. This bonding ties up electrons between the compounds, and thus results in very hard

materials that don't conduct electricity or heat very well. Ceramics tend to be used in load-bearing applications for instance roads, buildings, dinnerware, etc.

The final class of materials are the **plastics**. Plastics are novel man-made materials and were made in laboratories in the early 1900s but weren't really heavily used until the 1950s after World War II. Many of them are compounds that consists of carbon, hydrogen, and other nonmetallic elements that form a long chain linking one to another to form large molecules. The primary type of bonding involved is **covalent bonding**, where atoms share electrons directly between one another. Since the electrons are shared, they tend not to be given off and plastics are poor conductors of electricity. Furthermore, plastics tend to have low densities and be extremely flexible compared to other material types. What most students don't know is that the great majority of plastics come from the oil refinery industry and is produced through the same process from which we get gasoline. Plastics are also contributing to a great deal of environmental issues especially related to their disposal.

Callister, William D. Materials Science and Engineering An Introduction. Wiley & Sons, Inc. 2000.

ADVANCE PREPARATION:

1. Ensure that videos and slides are able to display properly. Alternatively, the slides may be given as a hand out or projected onto the wall- the content is rudimentary and is meant to engage students in classification of materials.
2. Prepare the poster paper for a Gallery Walk. This will require SIX stations. Either arrange desks around the room, use the lab tables, or the walls around the room. Print out the open-ended discussion questions and tape them onto the tops of these posters. Printing out the questions allows you to reuse the questions onto another plain poster paper if you teach many

classes. If you'd like, divide the space below the question into regions allowing student groups to provide their input. Discussion questions are in the questions powerpoint file, or are listed in the next section.

3. Also, if you'd like, pre-select the groups of students, there will be 6 groups. The optimum number of students is 3 but in general up to 5 can be accommodated into a group. Furthermore, if there are greater numbers of students in the class, then other open-ended materials questions can be used.

PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES:

1. 3 minutes. Introduce the gallery walk activity. Use the attached slide to lay down the ground rules. E.g
 - a. 4-person group
 - i. Leader
 - ii. Responder 1
 - iii. Responder 2
 - iv. Recorder
 - b. Students will have 6 questions, 3-5 minutes each. They can either add new information, elaborate on a preceding group's response, or dispute a preceding group's response in their own section.
 - c. They will return to their original station and summarize what's written
 - d. Present to class at end
2. 5 minutes. Show slides of the different types of materials or write on the board the classification name and have students respond to them. Some of the questions include
 - a. What is a material?

- b. What materials do you know of that are made of metals?
 - c. What materials are made of ceramics? [If students don't understand this term then show them a picture or hold up a stoneware plate or a glass window]
 - d. What materials are made of plastics?
3. Next, allow form the students into groups or have them arrange themselves into groups. Pass out a colored pencil or crayon to each group.
4. Allow each group to go to a station and begin working.
5. 20-32 minutes. The discussion questions should be the following:

- a. What makes a good or perfect bottle?

You've probably seen juice inside plastic bottles as well as glass bottles:

List one reason (not listed below already) why the plastic bottle might be more desirable than the glass.

List one reason why the glass bottle might be more desirable than the plastic bottle.

- b. Selecting the right plate

People use different materials to makes plates out of.

List one type of food (not listed already) that you might put on a plate.

Explain what properties make a 'good' plate. Why might it not be a good idea to make plates out of metal?

- c. Paper or Plastic?

What is one advantage (not listed below already) of plastic bags compared to paper bags?

What is one disadvantage?

What are paper bags made from? What about plastic bags?

d. Metals are unique

Name one or two uses (not listed already) where metals win out over ceramics or plastics.

Why are things made of metal and why wouldn't you use plastics or ceramics for something?

e. Long Lasting Materials

What is an example of an artifact [something man-made] from thousands of years ago?

What type of materials tend to last a long time or are passed down from generation to generation that you might see in a museum exhibit?

f. How do I conserve?

Materials have to come from somewhere. Unfortunately, at the rate the world is growing the materials are being used up.

Give an example of what your family does which might be able to help decrease the amount of materials you use.

6. 5 minutes. Have the students return to their original stations and summarize what their classmates have written. Ensure students are on task. If students have difficulties presenting, then have students sit down, and you can collect the responses and summarize them to the class.
7. 6 minutes. Present the summary of information.
8. Provide enough time for wrap up of the lesson- 10 minutes. During this time show the after activity slides regarding where plastics come from, and that there are many types of plastics. Next discuss what happens to plastics if they don't end up at the recycling center or the landfill- use the attached

greenpeace flash animation for assistance:

http://oceans.greenpeace.org/en/the-expedition/news/trashing-our-oceans/ocean_pollution_animation

And/or show the video on The Great Garbage Patch news story regarding the trail of floating plastics in Hawaii- if there's not enough time to show the animation, then this should be shown instead:

<http://kgmb9.com/main/content/view/1706/40/>

9. Show slide regarding the need to balance human progress with the environment and have students consider it or respond to it as an assignment:
 - How do we balance the importance of the environment with technology, convenience, and human progress?

ASSESSMENT SUGGESTIONS:

1. For objective 1: Identify the use of materials in their daily lives.
 - a. In the next class: Have students take out a sheet of paper and consider the different materials in the classroom and provide an example of each of the three classes of materials.
 - b. Also, you could display various items made of plastic and one metallic item and ask which does not belong and why.
2. For objective 2: Consider positive and negative effects of a materials selection choice.
 - a. Ask about how you would go about heating up food in a variety of containers: can, plastic container, or glass dish. Would you use the same heat source for all materials?
 - b. Ask whether why might we use a ceramic dish over a plastic dish and have the students give responses for different cases.

3. For objective 3: Identify characteristic properties of certain types of materials.
 - a. See if students can understand that in general ceramics are brittle. Ask what happens if you take a hammer and smash a window or a plate vs what happens if you smash a metal sheet like aluminum foil or plastic bottle.
 - b. See if students understand that metals are usually used to make tools. Ask whether you want a hammer to be made of glass, plastic, or metal.
 - c. Alternatively, see if students understand metals are important materials to conduct electricity. Ask why wall outlets are made of ceramic or plastic rather than metals.
 - d. Ask why plastics are used in so many drink bottles. See if students understand that plastics are durable, yet light.
4. For objective 4: Provide insight into how conservation takes place in their family units.
 - a. Ask students why it's important to recycle.
 - b. Ask students whether there's another use for old plastic containers.

EXTENSIONS:

ACTIVITIES:

- The introduction activity may also be accomplished by showing the types of materials used to hold beverages: paper carton (natural material) and glass bottle, metal can, plastic bottle (processed materials).
- The strange matter exhibit site has a teacher's guide of various introductory activities such as creating a materials time line using online resources and searching for when certain materials were used.

- Have students consider what alternatives there are to existing materials in use, i.e. what would happen if all plastics were to disappear.

LITERATURE:

- <http://www.strangematterexhibit.com/whatis.html>
- http://www.jhu.edu/~matsci/people/faculty/erlebacher/what_is_materials_science.htm
- Callister, William D. Materials Science and Engineering : An Introduction. New York: Wiley, 1999.
- Askeland, Donald R. The Science and Engineering of Materials. New York: P W S, 1994.

RESOURCES/REFERENCES:

- "Plastic Resin Codes." The Saint Louis County Resourceful Schools Project. The Saint Louis County Resourceful Schools. 21 Jan. 2009 <<http://www.resourcefulschools.org/2006/resin-codes-poster.jpg>>.
- "The Recycling Process." How-To Booklet: Recycling. TAGS Hardware products. 21 Jan. 2009 <<http://www.tagshardware.com/recycle.html>>.
- Jolade Pty Ltd. 21 Jan. 2009 <<http://www.jolade.com.au/images/environment2.jpg>>.
- "Greenpeace | Pacific trash vortex showing drift of ocean pollution." Defending our Oceans | Greenpeace International. 21 Jan. 2009 <http://oceans.greenpeace.org/en/the-expedition/news/trashing-our-oceans/ocean_pollution_animation>.

- "15-Mile Long Garbage Trail Off Big Island Waters | KGMB9 News Hawaii."
[KGMB9 News Hawaii - Homepage](http://kgmb9.com/main/content/view/1706/40/). 21 Jan. 2009
 <<http://kgmb9.com/main/content/view/1706/40/>>.

SUNSHINE STATE STANDARDS:

Standards and References linked to this lesson:

FL Sunshine Stds:

{SC.A.1.3.1} identifies various ways in which substances differ (e.g., mass, volume, shape, density, texture, and reaction to temperature and light).

{SC.A.1.3.5} knows the difference between a physical change in a substance (i.e., altering the shape, form, volume, or density) and a chemical change (i.e., producing new substances with different characteristics).

{SC.A.2.3.2} knows the general properties of the atom (a massive nucleus of neutral neutrons and positive protons surrounded by a cloud of negative electrons) and accepts that single atoms are not visible.

{SC.D.1.3.3} knows how conditions that exist in one system influence the conditions that exist in other systems.

{SC.D.2.3.2} knows the positive and negative consequences of human action on the Earth's systems.

{SC.G.1.3.4} knows that the interactions of organisms with each other and with the nonliving parts of their environments result in the flow of energy and the cycling of matter throughout the system.

{SC.G.2.3.1} knows that some resources are renewable and others are nonrenewable.

{SC.G.2.3.4} understands that humans are a part of an ecosystem and their activities may deliberately or inadvertently alter the equilibrium in ecosystems.

{SC.H.2.3.1} recognizes that patterns exist within and across systems.

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LESSON 2: THE WAY STUFF BREAKS/FAILURE OF MATERIALS

KEY QUESTION(S): What does "mechanical property" mean? What are the various ways in which materials break? How can the properties of a material change depending on environment? How does processing affect the mechanical properties of materials?

SCIENCE SUBJECT: Physics and properties of materials.

GRADE LEVEL: 8th

SCIENCE CONCEPTS: Materials Classifications, Selection, and Processing

OVERALL TIME ESTIMATE: 100 minutes (2 50-minute classes)

LEARNING STYLES: Visual, Auditory, and Kinesthetic

VOCABULARY:

- Brittle
- Ductile
- Failure
- Stress
- Strain
- Elastic deformation
- Plastic deformation
- Fracture
- Strength
- Toughness
- Ductility

LESSON SUMMARY: Students are given various types of materials and are told to find a way to break them as a group. They are provided with the opportunity to synthesize their individual and collective understanding on the ways things are broken. The subsequent follow up to the "Failure of Materials" activity will help provide the importance of how environment affects a material's properties.

STUDENT LEARNING OBJECTIVES:

The student will be able to:

5. Identify different methods of causing mechanical deformation.
6. Identify elastic vs plastic deformation.
7. Provide insight that the environment has an impact on the mechanical property of a material.

MATERIALS:

- | | |
|--|---|
| <ol style="list-style-type: none"> 4. Tools: Hammer [crushing],
Pliers [twisting] 5. Various candy samples: soft such as gummy worms, hard such as peppermints.
Skittles work well to demonstrate a material whose mechanical properties depend on the type of force applied. 6. Magnifying glass | <ol style="list-style-type: none"> 7. Paper towels 8. "Failure of Materials" worksheet 9. Modeling clay / Play-Doh 10. Blow Torch or high-temp heating device 11. Automotive steel wire or bobby pins 12. Computer with internet access and projector |
|--|---|

BACKGROUND INFORMATION/LESSON GUIDE:

This second lesson examines the mechanical properties of materials and their modes of failure. Students have an understanding already that things break. They know that toys break, that balloons pop, or that when dropped, the functionality of a product is compromised (**failure**). The goal of this lesson is to develop observational skills in students and to get them to examine the surfaces of broken objects.

When a load or force is acting on a material, the material distributes the force over its entire body. This distribution of force over a cross-sectional area is called **stress**. The stress leads the material to respond by **strain**, a change in length.

Likewise, when a material is strained, or elongated, then that process results in a stress on the material to oppose the strain. To test the mechanical properties of a material, scientists use a machine called a 'tensile tester' which elongates a material while measuring the force required. This force can be divided by the cross-sectional area of the material to arrive at the stress. A stress vs strain graph is generated to help provide some information on a material's various mechanical properties.

A material under stress undergoes two stages of deformation. The first is **elastic deformation** which represents the stretching of atomic bonds; and once the force is removed, the material un-stretches or recovers the deformation. Elastic deformation can be visualized by using a rubber band and stretching it, once the force is removed, the deformation is recovered and the material returns to its original shape. After reaching an elastic limit, a material will undergo **plastic deformation**, or a permanent rearrangement of atoms which is un-recoverable once the force is removed. To visualize this, simply bend a paper clip, once the force is removed, the material maintains its deformed state.

As the stress and strain within a material increases, there will come a point when the material will fail and **fracture** (or break, developing new surfaces). There are two different types of modes of fracture, each mode corresponding to the principle mechanism by which brittle materials or ductile materials fail. The terms reflect the extent to which a material can experience plastic deformation before fracturing. The more **ductile** a material is the greater the ability for the material to plastically deform before fracturing. Ductile materials tend to be able to absorb a lot of energy as the atoms are being rearranged. **Brittle** materials, on the other hand, tend to have very little or no plastic deformation before fracturing.

Whether a material undergoes ductile and brittle fracture is dependent on a lot of factors such as temperature and the rate at which a force is applied. For instance, a soft, ductile material such as chewy candy can be placed into the freezer. The temperature causes the material to fail in a brittle manner when force is applied. An extreme example can be observed by taking flowers and placing them into liquid nitrogen. Once frozen, the petals will be extremely brittle and will shatter when crushed. Likewise, if a material such as putty or play-doh is stretched slowly, it acts as a very ductile, soft material. However, if we increase the rate at which we pull the material, it will undergo a higher degree of brittle failure.

Usually, ductile materials are favored since prior to their failure, there is some ability to forecast that a fracture is imminent. For instance, a metal spoon may bend, dent, or exhibit other modes of plastic deformation. On the other hand, brittle materials tend to have cracks that spread quickly and usually will extend well beyond the region where the force is being applied. An example of this is a ceramic plate which falls and shatters.

The **strength** of a material is related to the maximum amount of stress a material can take before failure occurs. The **toughness** of a material is how much energy a material can store, usually in the form of plastic deformation, before it breaks. A good way to visualize this is to think of the movie Rocky. Usually, the movies have him pitted against an opponent with higher strength (they can handle a lot of stress and are powerful), but none of them are as tough, i.e. can't take the amount of punches, as Rocky can take. No matter how much Rocky is deformed or how often he's knocked down, he still gets back up and his resolve does not *fracture*.

One final note which might be interesting for students is that the processing of a material can change its property from ductile to brittle. For instance, steel which is primarily made of iron atoms can be brittle or ductile depending on how it is heat treated. If you take a bobby pin and heat it up until it glows red-hot, then allow it to cool slowly, the pin will be very soft and flexible. However, if one heats it up and cools it rapidly in cold water, the bobby pin will be very brittle. This occurs because when heat is applied, the material takes in carbon from the atmosphere, as it cools slowly, the carbon is expelled out of the metal, forming ash on the outside, but the metal is still soft and ductile. But when the metal is quenched in water, the carbon atoms get stuck between the iron atoms and hinder their ability to move, and that's why the material is more brittle. Now, this process can be reversed by heating up the pin again and allowing it to cool slowly.

Callister, William D. Materials Science and Engineering An Introduction. Wiley & Sons, Inc. 2000.

ADVANCE PREPARATION:

4. Obtain different types of household materials that exhibit a range of mechanical properties from soft to very hard. Sugar candies are very relevant, since they're all made of sugar, but processed differently to achieve different properties. Each student or group should be able to have one of each of the materials. We used a peppermint, gummy worm, paper clip, rubber band, and skittles.
5. Have tools available for each group to aid in the fracture of materials and the drawing of the patterns: Hammers, pliers, scissors, magnifying glasses, colored pencils. Also, safety glasses are important.
6. Copy student worksheets.

7. For day two, prepare projector and computer and obtain play-doh or modeling clay, propane torch and an igniter. An alcohol burner could be used as a substitute. Bobby pins and tongs are also important. Heat resistant gloves and safety glasses are needed for safety.

PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES:

Day 1

10.5 minutes. Introduce the Failure of Materials lesson.

- a. Refresh the students' memory about physical changes and how they occur.
 - i. Ask students the various ways that could be used break things such as: stretching, crushing, twisting, and cutting
- b. Also, eliciting responses about the different types of materials and how they think it can be broken. It's important to focus on physical changes rather than chemical changes, e.g. burning, electrocuting, etc.

11. 10 minutes. Pass out worksheets and lay down the ground rules. E.g

- a. 3 or 4-person group
- b. Each student has a cup of different materials
- c. Worksheet instructions:
 - i. Provide qualitative and quantitative descriptions of each object first
 - ii. Next, identify what method of breaking the object will be undertaken
 - iii. Draw the setup of how the mechanical test will be done. It's important that students are very specific and include drawings of what they'll be doing, e.g. hitting with a hammer in a swift motion is different than crushing something slowly with a hammer.

- iv. Students will have to observe the object while experiment is being performed and make their observations in the "During testing box" - they can draw or write qualitative or quantitative descriptions- Such as discoloration or crack formation and location.
 - v. Students will also write down about or drawn the fracture surfaces once they've completed their mechanical testing on an object.
- d. Discuss safety. Students should wear safety glasses, and they must not play around in the lab such as swinging hammers wildly. Furthermore, instruct students to use paper towels to cover their candy if they plan on hitting it with a hammer. That will keep pieces from flying everywhere and also will keep the candy clean for consumption.
- e. Students should also be instructed to try different methods of breaking the same item since they'll be working in groups.

12. 30 minutes. Have students get into lab stations and begin to go through worksheet.

- a. Many students will have trouble breaking the paperclip or the rubber band. Try to lead them to consider twisting the paper clip back and forth over and over. Rubber bands may be stretched until they snap, or they can be cut.
- b. Ask students what other ways could be used to break each object.
- c. Ensure students fill out their worksheets and observations. Also, difficulties may arise when filling out observations during testing when using the hammer. Try to drive the student to understand that when using a hammer and brittle failure occurs, it occurs too fast to readily observe.

- d. Reserve the last 2 minutes for cleaning up and returning glasses before sitting down at their seats

13. 5 minute wrap up. Discuss students' observations and methods of breaking various types of materials. Ask about any difficulties in the lab. Elicit questions about the different foods they consume and the role their teeth have in breaking food down. Link this to recycling facilities and what type of tools they might use to break down used materials and provide new raw materials.

Day 2

1. 30 minutes. The follow up to the previous day's lab focuses on the engineering aspect. Now that the students have hands on experience on how materials fail, the terms should be easier for the students to grasp and relate. Relate the terms to what the students did when breaking their materials.
 - a. Show videos of how materials are tested by scientists. [See literature section]
 - b. Use Play-Doh to demonstrate ductile vs brittle by comparing slowly stretching with quickly stretching a piece.
 - c. Use the Rocky example in the background to help distinguish between strength and toughness. You can also relate to hitting a gummy worm with a hammer vs the peppermint, a stronger but less tough material.
2. 15 minutes [for entire demo]. For the final demonstration, wear safety glasses and use tongs to heat the joint of the bobby pin to glowing bright red hot.
 - a. Ask students what happens to molecules or atoms when they heat up. Direct them to respond that as things heat up, their atoms move more and more and in general, things begin to move apart and expand.
3. Allow the pin to cool slowly in air.

- a. Ask students what is on the outside of the pin? They should respond about it being ash. Direct students to figuring out what element ash is comprised of: carbon.
4. Once cooled or with tongs, bend the bobby pin and observe that it no longer springs back.
 - a. Ask students why doesn't it spring back? Direct students to respond that the material is now easier to bend, less stiff, and is softer or more ductile. Bend the metal back and forth and count the number of times until it breaks.
5. Now take another bobby pin and heat the joint until bright red/orange, this time cool immediately by quenching into cold water.
 - a. Ask students what they think will happen to the properties of the metal once quenched. Demonstrate that the material is now much more brittle by bending it back and forth until it breaks.
6. Now show a new bobby pin which hasn't been experimented upon. It should exhibit some useful properties: it's hard enough to spring back, but not so brittle.
 - a. Ask students to come up with ideas on how take a very soft bobby pin and make is harder, but not so hard that it's brittle. Furthermore ask how they can take something that's hard and brittle and make it softer.
7. The final step is to 'temper' the bobby pin so that it's hard but not too hard. This can be achieved by heating and quenching to get a very hard bobby pin, and then follow up with heating slightly [dull red] but not strongly. You can talk about sword making as well. Blacksmiths don't want swords which are too soft since it will bend easily; but they don't want a sword which is too hard, or it'll break easily.
8. 5 minutes. Last five minutes should be spent reviewing the key terms.

ASSESSMENT SUGGESTIONS:

5. For objective 1: Identify different methods of causing mechanical deformation.
 - a. Have students write out different ways to alter the physical property of a sheet of paper. They should be able to talk about crushing, tearing, squishing, folding, stretching.
 - b. For further assessment, ask how they could control the degree by which they mechanically deform an object and how they could go about measuring. A couple of examples include the weight used to crush, the number of folds, or the use of spring force gauges to measure force required to stretch and a ruler to measure the elongation.
6. For objective 2: Identify elastic vs plastic deformation.
 - a. Ask students to describe what happens right after crushing a can by stepping on it. Have them use the terms elastic deformation and plastic deformation. The student should be able to identify that the can springs back slightly once the force is removed and this represents the elastic deformation component. The rest of the can that's bent can be considered as plastic deformation.
7. For objective 3: Provide insight that the environment has an impact on the mechanical property of a material.
 - a. Ask students to explain why it's important to cars in the north to have a set of summer and a set of winter tires for their cars. First have students explain what the point of tires is; they should mention about how it is able to grip the road. Talk about what happens to tires when it gets colder. Do harder tires grip the road as well? Use something hard like a plastic wheel, and see how well it grips to the table, adding a rubber band around it improves the grip considerably. Winter tires are designed to be soft in much colder temperatures than summer tires. Furthermore, winter tires used in the summer will be too soft and wear out much faster.

ACTIVITIES:

- To discuss how processing affects a material, make different types of candies using a candy thermometer and sugar. See <http://en.wikipedia.org/wiki/Candy> for more information or <http://whatscookingamerica.net/Candy/candytemp.htm>
- Have students discuss how a recycling center might work to break down materials to make raw materials. One example of plastics is shown here: <http://earth911.com/plastic/video-how-plastic-gets-recycled/>

RESOURCES/REFERENCES:

- Callister, William D. Materials Science and Engineering : An Introduction. New York: Wiley, 1999.
- "Tensile Testing of HDPE." Daniel Samborsky. <http://www.youtube.com/watch?v=I28m4FZzqro>
- "Steel Rebar Tensile Test." Rutgers Civil Engineering <http://www.youtube.com/watch?v=YdqvGGFIbfc>
- "Can the Mettle of Metal be Improved?" Robert Farber. http://serendip.brynmawr.edu/sci_edu/farber/

SUNSHINE STATE STANDARDS:

Standards and References linked to this lesson:

FL Sunshine Stds

{SC.A.1.3.1} identifies various ways in which substances differ (e.g., mass, volume, shape, density, texture, and reaction to temperature and light).

{SC.A.1.3.3} knows that temperature measures the average energy of motion of the particles that make up the substance.

{SC.A.1.3.4} knows that atoms in solids are close together and do not move around easily; in liquids, atoms tend to move farther apart; in gas, atoms are quite far apart and move around freely.

{SC.A.1.3.5} knows the difference between a physical change in a substance (i.e., altering the shape, form, volume, or density) and a chemical change (i.e., producing new substances with different characteristics).

{SC.C.2.3.2} knows common contact forces.

{SC.C.2.3.3} knows that if more than one force acts on an object, then the forces can reinforce or cancel each other, depending on their direction and magnitude.

{SC.C.2.3.6} explains and shows the ways in which a net force (i.e., the sum of all acting forces) can act on an object (e.g., speeding up an object traveling in the same direction as the net force, slowing down an object traveling in the direction opposite of the net force).

{SC.D.1.3.3} knows how conditions that exist in one system influence the conditions that exist in other systems.

{SC.H.3.3.4} knows that technological design should require taking into account constraints such as natural laws, the properties of the materials used, and economic, political, social, ethical, and aesthetic values.



Name: _____

Period: _____

Date: _____

Failure of Materials

Every solid thing you eat has to be broken up somehow. Today, you're going to be a materials scientist. Each of the candy or other objects below represents a different type of material. It's up to you to write and draw about how each of the materials break. Some examples of ways you can go about breaking a material into smaller pieces include: crushing, stretching, bending, and tearing. Maybe you can think of your own way? You'll be in groups, so try a few different ways for each material. Remember, be careful, keep your safety glasses on, and keep your work area clean.

Peppermint - _____

Mechanical Test: _____

Setup	Observations During Test	Observations After Test

Gummy worm - _____

Mechanical Test: _____

Setup	Observations During Test	Observations After Test

Paper clip - _____

Mechanical Test: _____

Setup	Observations During Test	Observations After Test

Rubber band - _____

Mechanical Test: _____

Setup	Observations During Test	Observations After Test

Skittles – _____

Mechanical Test: _____

Setup	Observations During Test	Observations After Test

MATERIALS & ME

Created for **SPICE** by scientist Chris Woan and teacher Brett Cornelison
Fall 2008 / Spring 2009

LESSON 3: TOWARDS A SUSTAINABLE FUTURE

KEY QUESTION(S): What is waste and where does it come from and why do we have it? Where does our waste go? What alternatives are there to limit the amount of waste that ends up in the landfill?

SCIENCE SUBJECT: Environmental science.

GRADE LEVEL: 6-8th

SCIENCE CONCEPTS: Conservation, materials processing, environment

OVERALL TIME ESTIMATE: 50 minutes (one 50-minute class)

LEARNING STYLES: Visual, Auditory, and Kinesthetic

VOCABULARY:

- Waste
- Sustainability
- Recycling
- Downcycling
- Upcycling
- Biodegradable

LESSON SUMMARY: Students are asked how waste is generated. Their ideas are then categorized into Biological, Paper, Plastic, Metals, Glass, and/or Electronics. Next, students are prompted to discuss how each of these categories of waste is handled and where they go. Slides are shown of various landfills and how different waste is handled. Furthermore, the students are told about how discarded electronics were sent to other countries due to their toxicity. Once the importance of waste management is established, we can address how to better sustain the future through materials sustainability concepts such as the various forms of recycling.

STUDENT LEARNING OBJECTIVES:

The student will be able to:

8. Identify different ways of how waste is generated.
9. Provide various routes to handle waste.
10. Provide insight that waste management is an important component to a sustainable future.

MATERIALS:

13. Used and clean water bottles

14. Computer with internet access and projector

15. Student worksheets

BACKGROUND INFORMATION/LESSON GUIDE:

This third and final lesson examines how materials become waste, addresses the importance of limiting waste accumulation, and provides alternative routes for waste management. This final lesson ties all the materials properties and lessons back to how materials and our reliance them impact the environment.

Waste is the production of discarded and unwanted materials. It is generated by the manufacture, transport, use, and finally disposal of materials. Due to increased development of cheaper and tougher materials such as plastics, the waste produced by each individual in the US has increased from 2.7 to 4.4 lbs per day in the past 35 years. Furthermore, landfills are becoming full of materials which don't decompose or breakdown. The growth of waste production is adversely affecting the environment and reducing resources for future generations. **Sustainability**, or *the ability to meet the needs of the present without compromising the needs of future generations to meet their own needs*, has increasingly become an important

concept for industry, government, and consumers. The world has adopted strategies which are meant to help address the increased waste issues and provide a more sustainable future, this is widely known as the three R's to waste reduction.

Students will probably already know the three R's to a sustainable future: reduce, reuse, and recycle. Reducing waste means lessening purchases or finding alternatives which contribute less to the growth of landfills. Reusing products begins with choosing products that are extremely durable and may be easily cleaned- examples include ceramic plates, glass cups, silverware, rechargeable batteries. Unfortunately, the reuse of products is merely prolonging the cycle of a material which still ends in waste.

Recycling requires that materials be reprocessed and broken back down into raw materials before starting a new life-cycle again. There are four different pathways of recycling. The usual concept of recycling is to remanufacture the same product. However, recycling also entails downcycling, upcycling, and biodegrading.

Downcycling is the recycling of materials into products of a lesser value— and which typically cannot be subsequently recycled. Examples include converting plastic bottles into particle board or combined with wood chips and dust to make lumber for construction, converting glass into Glasphalt a substitute for asphalt used to pave roads, or making an athletic track from old tires. The downside of this process is that these materials usually end up in the landfill at the end of their lifecycle.

Upcycling is the practice of taking something that is disposable and transforming it into something of greater use and value. For instance, the use of recycled aluminum cans to make body panels for vehicles or aircraft engine components. Furthermore,

upcycling may also include old products which are used as raw components to works of art.

Finally, **biodegrading** is the ability for materials to naturally break down back into its basic raw material components. This means that no waste is actually accumulated. One of the best examples of innovative use of biodegradable products is the use of plant-based plastics. Industry has developed cornstarch-based utensils which when discarded or composted can easily degrade back into soil.

ADVANCE PREPARATION:

8. Collect used plastic bottles.
9. Prepare slides and worksheets for students.

PROCEDURE AND DISCUSSION QUESTIONS WITH TIME ESTIMATES:

14. 10 minutes. Introduce where waste comes from.
 - a. Elicit responses about the different types of materials waste. Categorize waste between biological, paper, plastic, metal, ceramic, and electronic.
 - b. Ask where waste goes. Usually students say that it gets carried off. Probe further to see whether students understand what happens to the waste when it gets carried off.
15. 10 minutes. Show students the images of landfills.
 - a. Identify what they see most predominantly. Students should be able to say that they see a lot of plastic bags.

- b. Show the images of electronics being scavenged in India. Discuss about countries including the US who used to widely dispose of old electronics by sending the waste to other countries due its toxicity [see references] and cheap labor to melt and recover precious metals.
- c. Discuss the morality of disposing toxic waste by sending it to other countries.

16. 15 minutes. Discuss where waste goes and what happens to waste.

- a. Biological/organic waste usually decomposes back into soil.
- b. Paper waste may be recycled or may decompose.
- c. Plastic, glass, and metal waste goes to the landfill, recycling center, or ends up in nature.
- d. Recycling
 - i. Students usually have difficulties discerning between reusing and recycling. Note that reusing means taking something old and continuously perform its function over and over. Whereas recycling means that old things are converted to raw materials again.
 - ii. Show video [see references for earth911.com site] of how various materials are recycled.
- e. Downcycling
 - i. Ensure students understand that downcycled goods usually end up as waste eventually.
- f. Upcycling
 - i. Discuss what sort of materials are usually upcycled: durable materials such as metals or ceramics, that can be processed over and over with little or no degradation.
 - ii. Art work is also an example of upcycling.

- g. Biodegradability and plant-based plastics
 - i. Show video on composting [see reference].
 - ii. Biodegradability means no eventual waste results from an object's disposal.

17. 15 minutes. Provide students with used water bottles and have them brainstorm on how to creatively upcycle the material.

ASSESSMENT SUGGESTIONS:

- 8. For objective 1: Identify different ways of how waste is generated.
 - Ask students to write about how waste is generated when a pencil is made from trees and ends up in the student's hands.
 - Furthermore, ask students about making a cake and the waste generated along the way of manufacturing, transportation, consumption, and finally, even the result of digestion.
- 9. Provide various routes to handle waste.
 - Ask students to draw out a diagram of the various routes a plastic bag from the supermarket can go. Students should be able to discuss its reuse, its recycling, its collection as waste, or even its use in art work.
- 10. Provide insight that waste management is an important component to a sustainable future.
 - Ask students to draw how the future will look if the landfill gets full. What happens when we no longer have a place to throw our trash away?

EXTENSIONS:

ACTIVITIES:

- Have students construct an art project with materials which were destined for waste facilities.

- Make stoves with aluminum cans:
http://en.wikipedia.org/wiki/Beverage-can_stove
- Make a car from fast food drinking cups, lids, and straws
- Students may also perform a paper-recycling activity.
 - <http://www.instructables.com/id/How-to-Make-and-Recycle-Paper/>

RESOURCES/REFERENCES:

- Sustainable information and slide pictures came from a presentation on "Materials Sustainability" by Dr. Amelia Dempere of the University of Florida Department of Materials Science and Engineering.
- General information on waste:
 - http://recycling.colorado.edu/education_and_outreach/recycling_facts.html
- Information on e-waste:
 - <http://www.usatoday.com/tech/news/2002/02/25/computer-waste.htm>
 - <http://www.indiatogether.org/2003/may/env-ewaste.htm>
 - <http://www.reuters.com/article/technologyNews/idUSPEK14823020070611>
 - <http://www.rediff.com/money/2006/aug/15ewaste.htm>
 - http://en.wikipedia.org/wiki/Electronic_waste
- Recycling videos:
 - Paper: <http://earth911.com/paper/video-how-paper-gets-recycled/>
 - Metal: <http://earth911.com/metal/video-how-metal-gets-recycled/>

- Plastic: <http://earth911.com/plastic/video-how-plastic-gets-recycled/>
- Glass: <http://earth911.com/glass/video-how-glass-gets-recycled/>
- Composting video:
http://www.castlepoint.gov.uk/flash/Recycling/Compost/Compost_animation.swf

SUNSHINE STATE STANDARDS:

Standards and References linked to this lesson:

FL Sunshine Stds

{SC.B.1.3.2} knows that energy cannot be created or destroyed, but only changed from one form to another.

{SC.B.1.3.4} knows that energy conversions are never 100% efficient (i.e., some energy is transformed to heat and is unavailable for further useful work).

{SC.B.2.3.2} knows that most of the energy used today is derived from burning stored energy collected by organisms millions of years ago (i.e., nonrenewable fossil fuels).

{SC.D.1.3.2} knows that over the whole Earth, organisms are growing, dying, and decaying as new organisms are produced by the old ones.

{SC.D.1.3.3} knows how conditions that exist in one system influence the conditions that exist in other systems.

{SC.D.1.3.4} knows the ways in which plants and animals reshape the landscape (e.g., bacteria, fungi, worms, rodents, and other organisms add organic matter to the soil, increasing soil fertility, encouraging plant growth, and strengthening resistance to erosion).

{SC.D.2.3.1} understands that quality of life is relevant to personal experience.

{SC.D.2.3.2} knows the positive and negative consequences of human action on the Earth's systems.

{SC.G.1.3.4} knows that the interactions of organisms with each other and with the nonliving parts of their environments result in the flow of energy and the cycling of matter throughout the system.

{SC.G.2.3.1} knows that some resources are renewable and others are nonrenewable.

{SC.G.2.3.2} knows that all biotic and abiotic factors are interrelated and that if one factor is changed or removed, it impacts the availability of other resources within the system.

{SC.G.2.3.3} knows that a brief change in the limited resources of an ecosystem may alter the size of a population or the average size of individual organisms and that long-term change may result in the elimination of animal and plant populations inhabiting the Earth.

{SC.G.2.3.4} understands that humans are a part of an ecosystem and their activities may deliberately or inadvertently alter the equilibrium in ecosystems.